RANGE PAYLOAD DIAGRAM

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Sources:

Fielding, J. P., *Introduction to Aircraft Design*, Cambridge Aerospace Series 11, 1999
Ackert, S., *Aircraft Payload-Range Analysis for Financiers*, *Aircraft Monitor*, 2013

Definitions

- Range
  - Distance that an a/c can cover during flight
- Payload:
  - Total weight for which airline gets "paid"
    - Passengers, Baggage, Cargo
- Trade-off between Range & Payload
  - Range-Payload Diagram

Depends on perspective !

AIRCRAFT WEIGHT BREAKDOWN

Manufacturer's Perspective

- Maximum Ramp Weight (MRW)
- Maximum Takeoff Weight (MTOW)
- Maximum Landing Weight (MLW)
- Maximum Zero Fuel Weight (MZFW)
- Authorized Limit v/s Structural Limit

Operator's Perspective

- Manufacturer's Empty Weight (MEW)
- Standard Items (SI)
  - Unusable fuel, Engine oil, Toilet fluids & Chemicals
  - Fire extinguishers & emergency O_2 equipment
  - Galley structures & Supplementary electronic eqpt.
- Operator Items (OI)
  - Crew + Baggage, Documents, Seats, Life Rafts & Vests
  - Food and Beverages
- Operating Empty Weight (OEW)
  - OEW = MEW + SI + OI
- Maximum Payload
  - Passengers + Baggage + Cargo

Boeing 737-800

Certified Weight	Operational Max. (1000 lb)	Structural Max. (1000 lb)
MRW	156.2	174.9
MTOW	155.5	174.2
MLW	144.0	146.3
MZFW	136.0	138.3

Typical Aircraft weight build-up

- $W_{ramp} = W_{warmup} + W_{taxi} + W_{TORun} + W_{TO}$
- $W_{TO} = W_{pay} + W_{fuel} + W_{Ops\text{-}empty}$
- $W_{Ops\text{-}empty} = W_{str} + W_{crew} + W_{Ops.\ Items}$
- $W_{Ops.\ Items} = W_{F\&B} + W_{mags} + W$ ....
- W_{fuel} = Mission Fuel + Reserve Fuel
- $W_{pay} = W_{pax} + W_{baggage} + W_{cargo}$
- Limitations on W_{pay}
  - Volume
  - Structural strength of Cargo bay

Source: http://i.ytimg.com/vi/ZJYHwnV-nO4/maxresdefault.jpg

Example of Weight Build-up

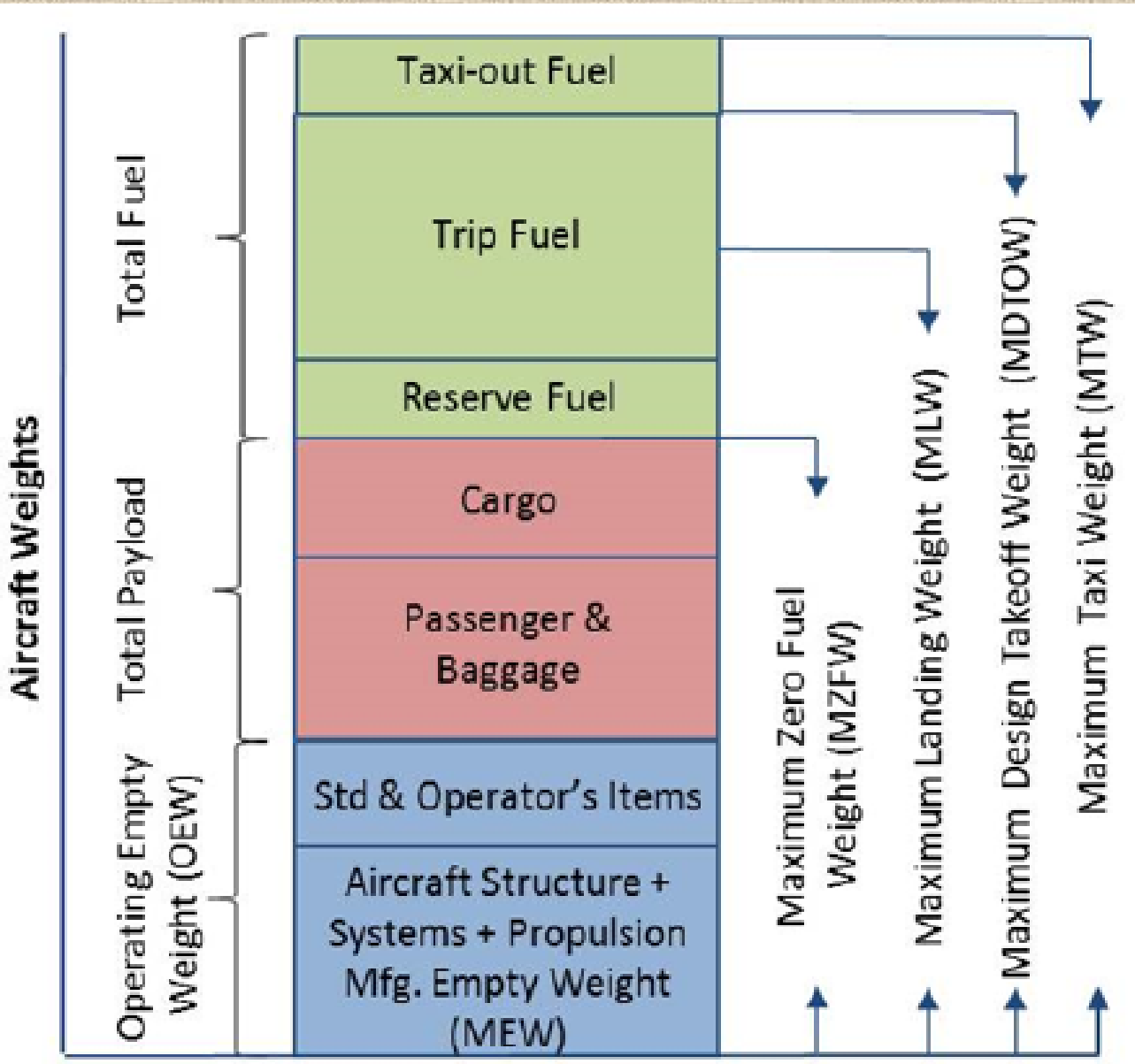
Avro-RJ 100 *Whisperjet*

Regional Jet Transport Aircraft

Weight Build-up

- Specs
  - Max Takeoff Weight — MTOW — 44226
  - Max Landing Weight — MLW — 40143
  - Max Zero Fuel Weight — MZFW — 37422
  - Operating Empty Weight — OEW — 25600
  - Max Fuel Capacity = 11728 liters
  - Max. no of Passengers — n_{pax} — 112
- Calculated Values
  - Max Payload Weight = (MZFW-OEW) — MPW — 11822
  - Max Fuel Weight — MFW — 9242
- Payload + Fuel = MTOW-OEW — 18626

Aircraft Weight Buildup



Source: Ackert, S., Aircraft Payload-Range Analysis for Financiers, *Aircraft Monitor*, 2013

Maneuver Allowances

- Engine start & Pre-taxi checks 18 kg
- Taxi (all engines) 89 kg
- Takeoff (estimate) 50 kg
- Approach & Land 143 kg

- WARMUP + TAXI + TAKEOFF 300kg

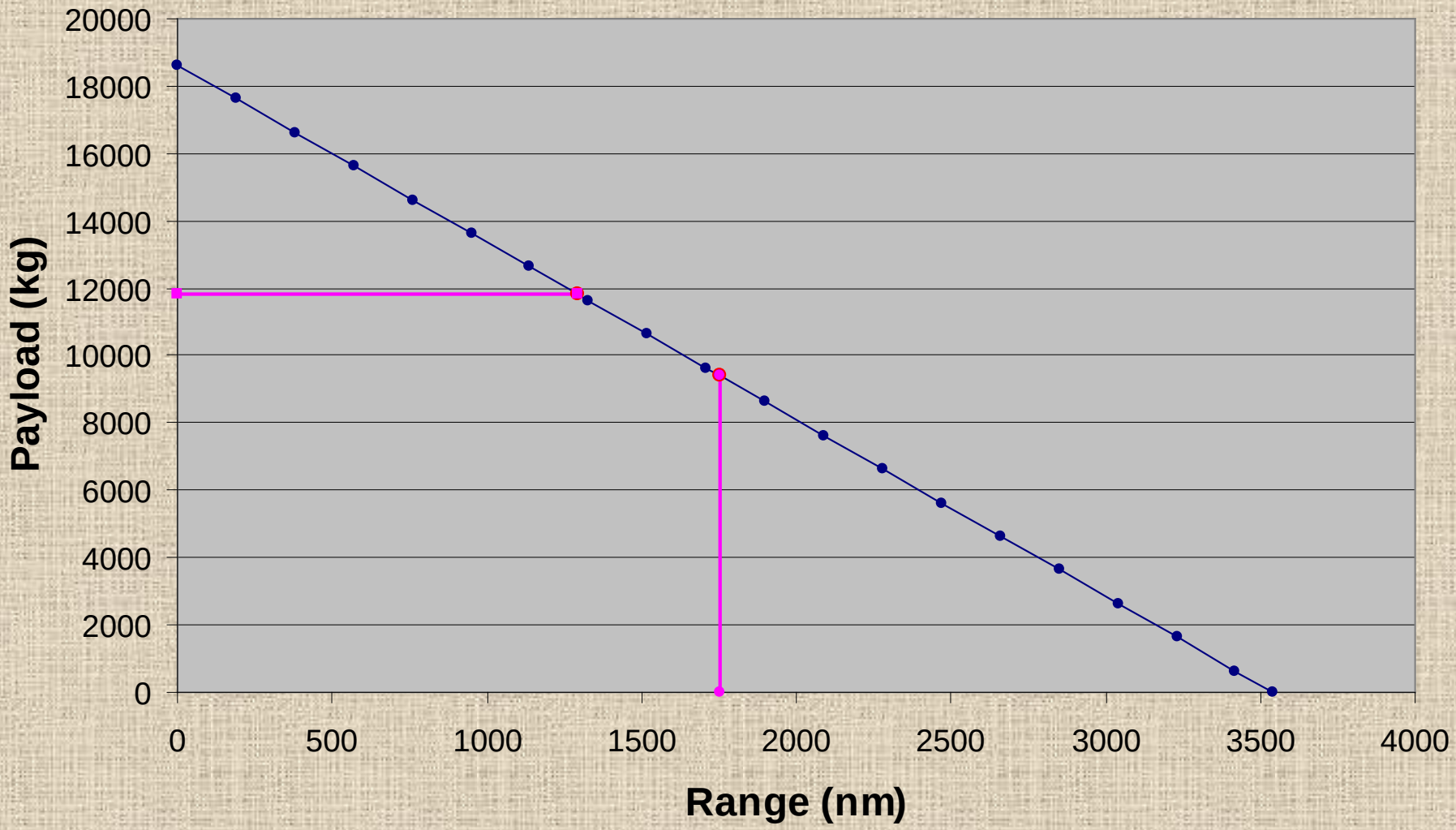
Weight Breakdown @ Max Payload

- Ramp Weight 44526
  - Warmup + Taxi + Takeoff 300
- Takeoff Weight 44226
  - Payload 11822
    - 112 Pax @ 95 kg each 10640
    - Cargo 1182
  - Fuel 6804
    - Reserve Fuel (assumed 0.85* Fuel) 1021
- Operating Empty Weight 25600
  - Structure 23925
  - Crew 375
  - Ops Items 1300

Range-Payload Diagram

Avro-RJ-100 aircraft

(Assuming Payload + Fuel = 18626 kg, and 0.19 nm/kg)



Two important points

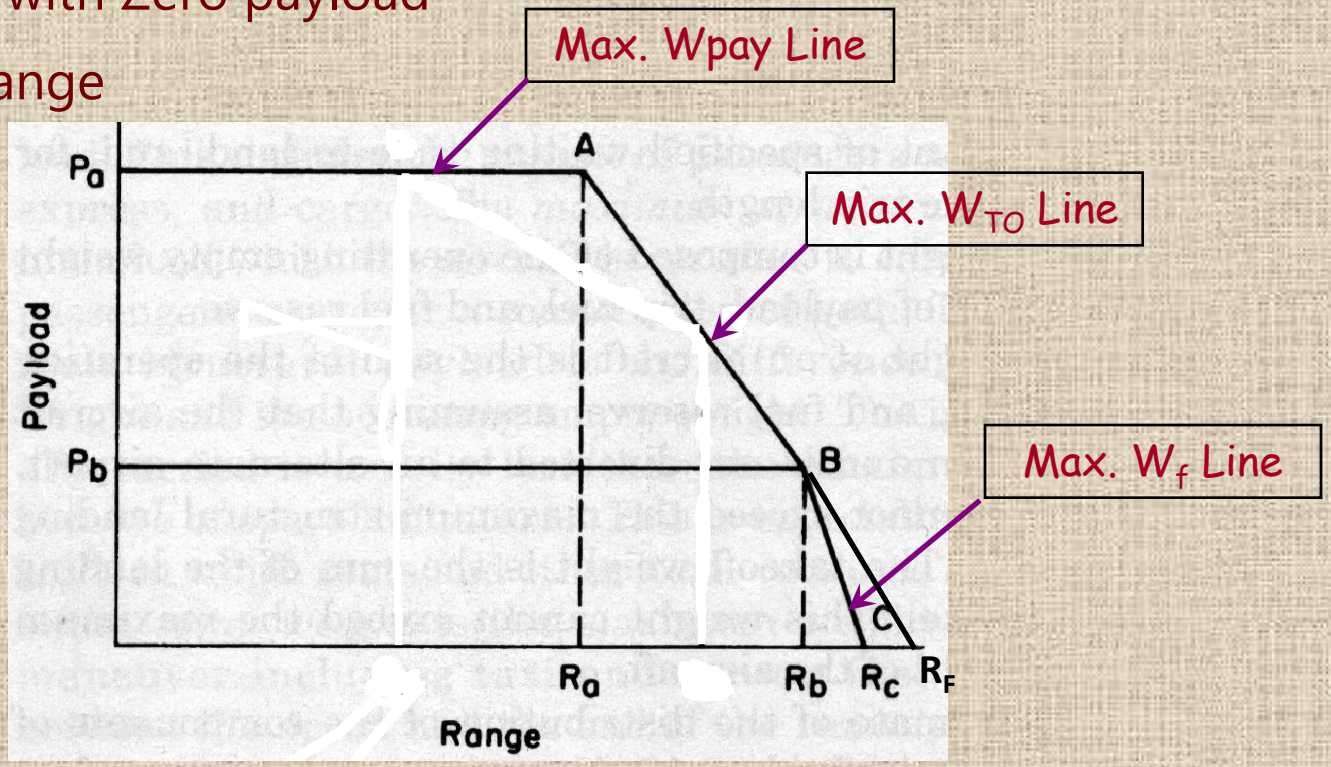
- All Fuel is not useable !
  - Missed Approach, Diversion & Hold 3.5%
  - Navigational errors and en Route weather 10.0%
  - Trapped Fuel 1.5%
    - Mission Fuel = Total Fuel - Reserve Fuel = 0.85*Total Fuel
- Specific Range is not constant !
  - Increases as aircraft becomes lighter

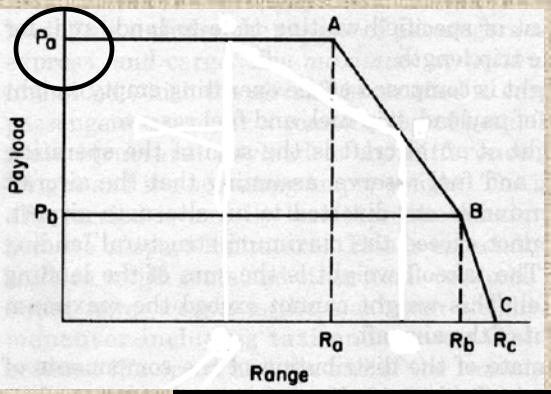
Three types of Range

- Harmonic Range
  - Range with maximum possible payload
- Ferry Range
  - Range with zero payload, and including reserve fuel
- Gross Still Air Range
  - Range assuming all the mission fuel is utilized for cruise flight alone

RPD calculation

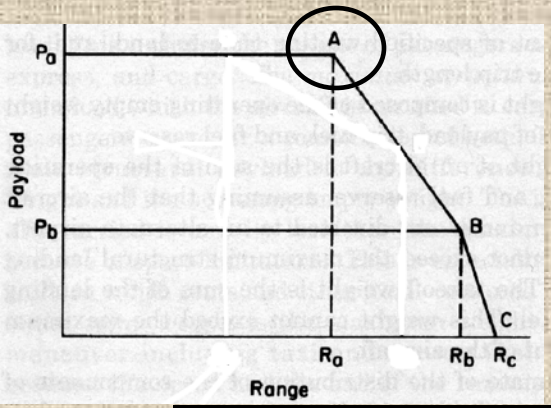
- P_a = MPW & R_a = Harmonic Range = max Range @ P_a
- If we need Range > R_a, Tradeoff between W_{pay} & W_{fuel}
  - R_b = Range with Max Fuel & W_{pay} of P_b
- If we need more Range than R_b, Reduce $W_{payload}$
- R_C = Range with Zero payload
- R_F = Ferry range





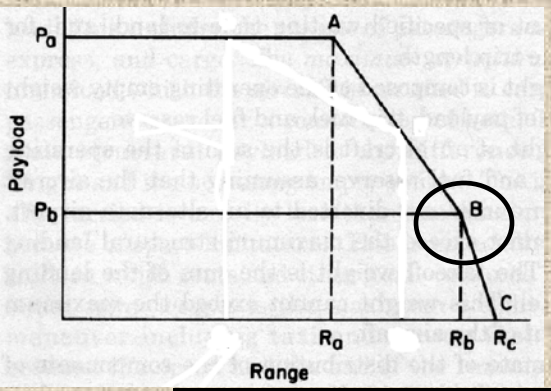
RPD Calculation Point - P_a

Pt.	Payload	TOW	FW	Range
P_a	MPW	MZFW	Zero	Zero



RPD Calculation Point A

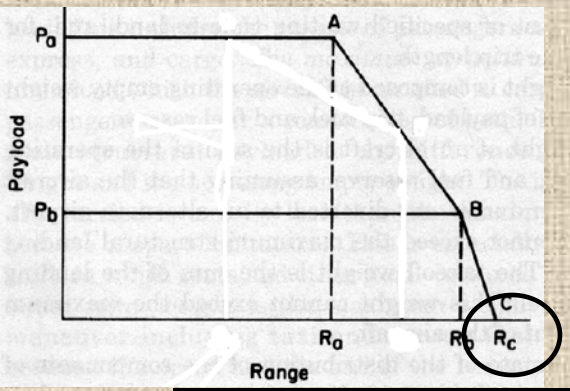
Pt.	Payload	TOW	FW	Range
A	MPW	MTOW	MTOW-MPW -OEW	(FW-RF)*SR



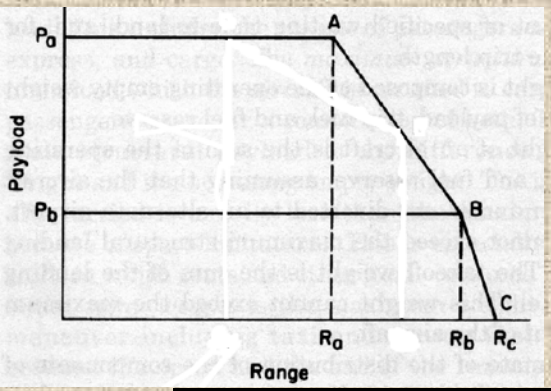
RPD Calculation Point B

Pt.	Payload	TOW	FW	Range
B	MTOW -OEW -MFW	MTOW	MFW	(MFW-RF)*SR

RPD Calculation
Point C



Pt.	Payload	TOW	FW	Range
C	Zero	OEW+MFW	MFW	FW*SR



RPD Calculation Table

Pt.	Payload	TOW	FW	Range
P_a	MPW	MZFW	Zero	Zero
A	MPW	MTOW	MTOW-MPW-OEW	(FW-RF)*SR
B	MTOW-OEW-MFW	MTOW	MFW	(MFW-RF)*SR
C	Zero	OEW+MFW	MFW	FW*SR

RPD calculation for Avro RJ-100

Note: Assuming SR = 0.19 nm/kg

MTOW = 44226 MPW = 11822 MFW = 9242

OEW = 25600 RF = 1386 MZFW = 37422

Pt.	Payload	TOW	FW	Range
P_a				
A				
B				
C				

RPD calculation for Avro RJ-100

Note: Assuming SR = 0.19 nm/kg

MTOW = 44226 MPW = 11822 MFW = 9242

OEW = 25600 RF = 1386 MZFW = 37422

Pt.	Payload	TOW	FW	Range
P_a	11822		Zero	Zero
A	11822	44226		
B		44226	9242	
C	Zero		9242	

RPD calculation for Avro RJ-100

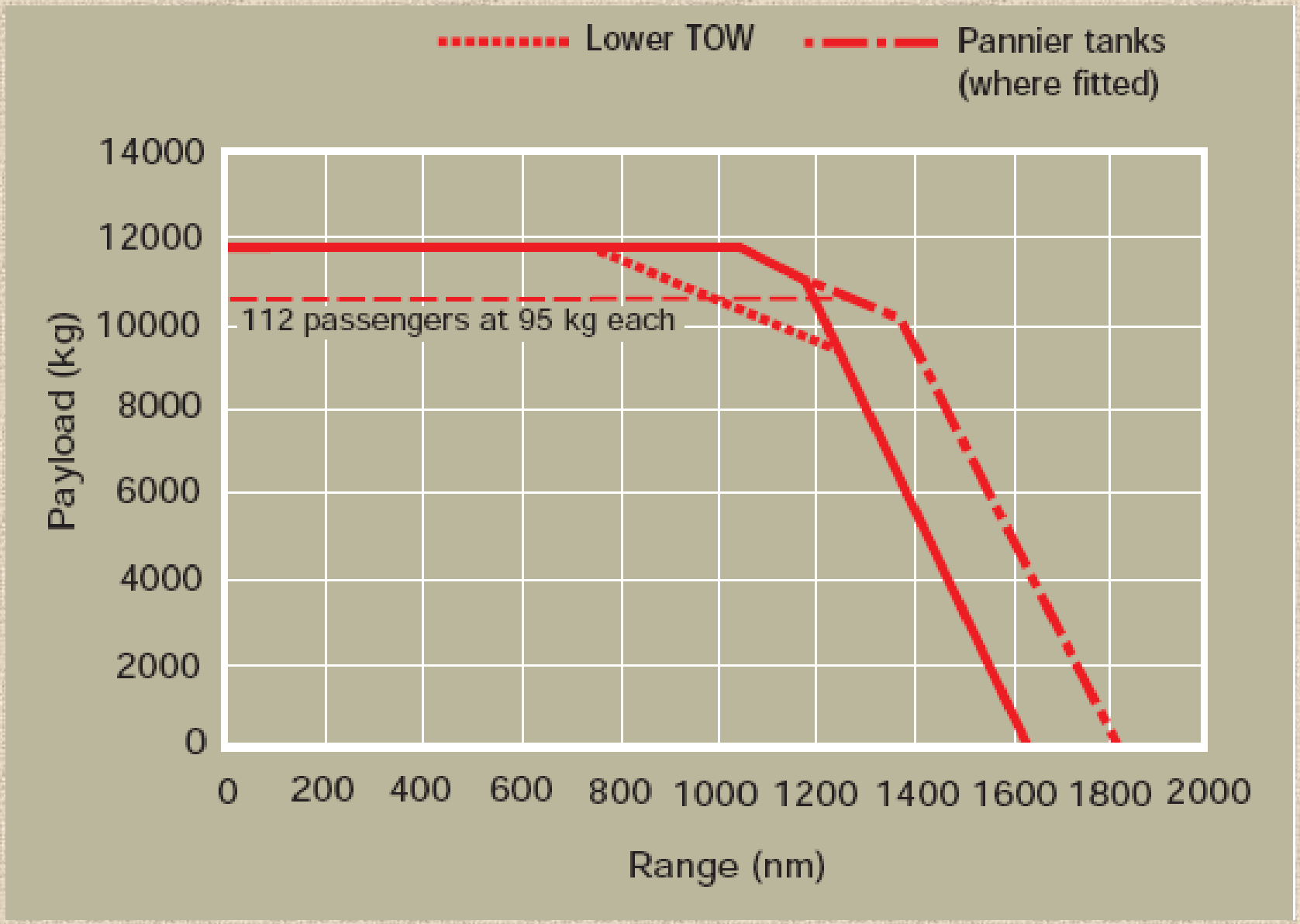
Note: Assuming SR = 0.19 nm/kg

MTOW = 44226 MPW = 11822 MFW = 9242

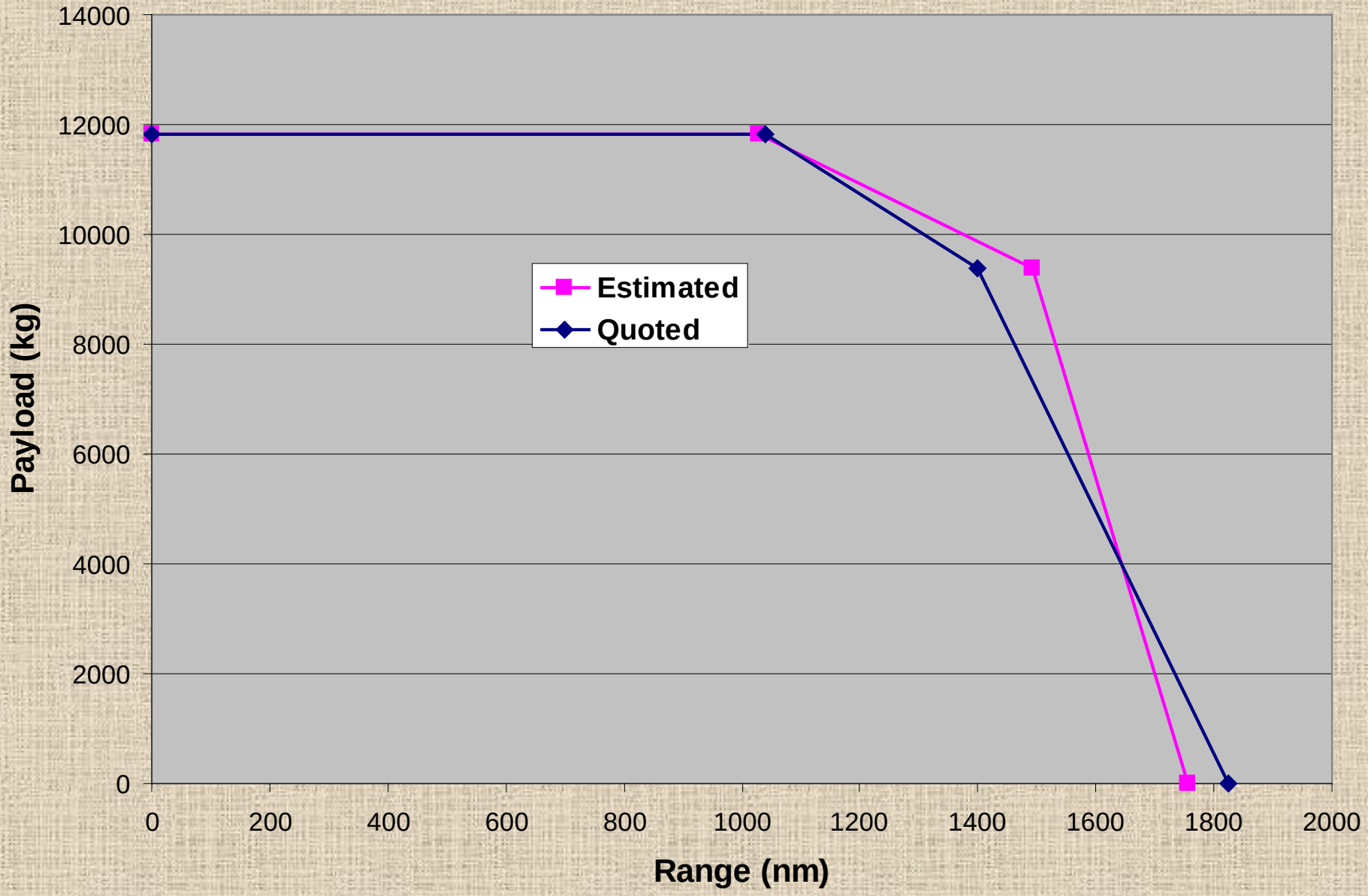
OEW = 25600 RF = 1386 MZFW = 37422

Pt.	Payload	TOW	FW	Range
P_a	11822	37422	Zero	Zero
A	11822	44226	6804	1029
B	9384	44226	9242	1493
C	Zero	34842	9242	1756

Actual RPD of Avro-RJ-100



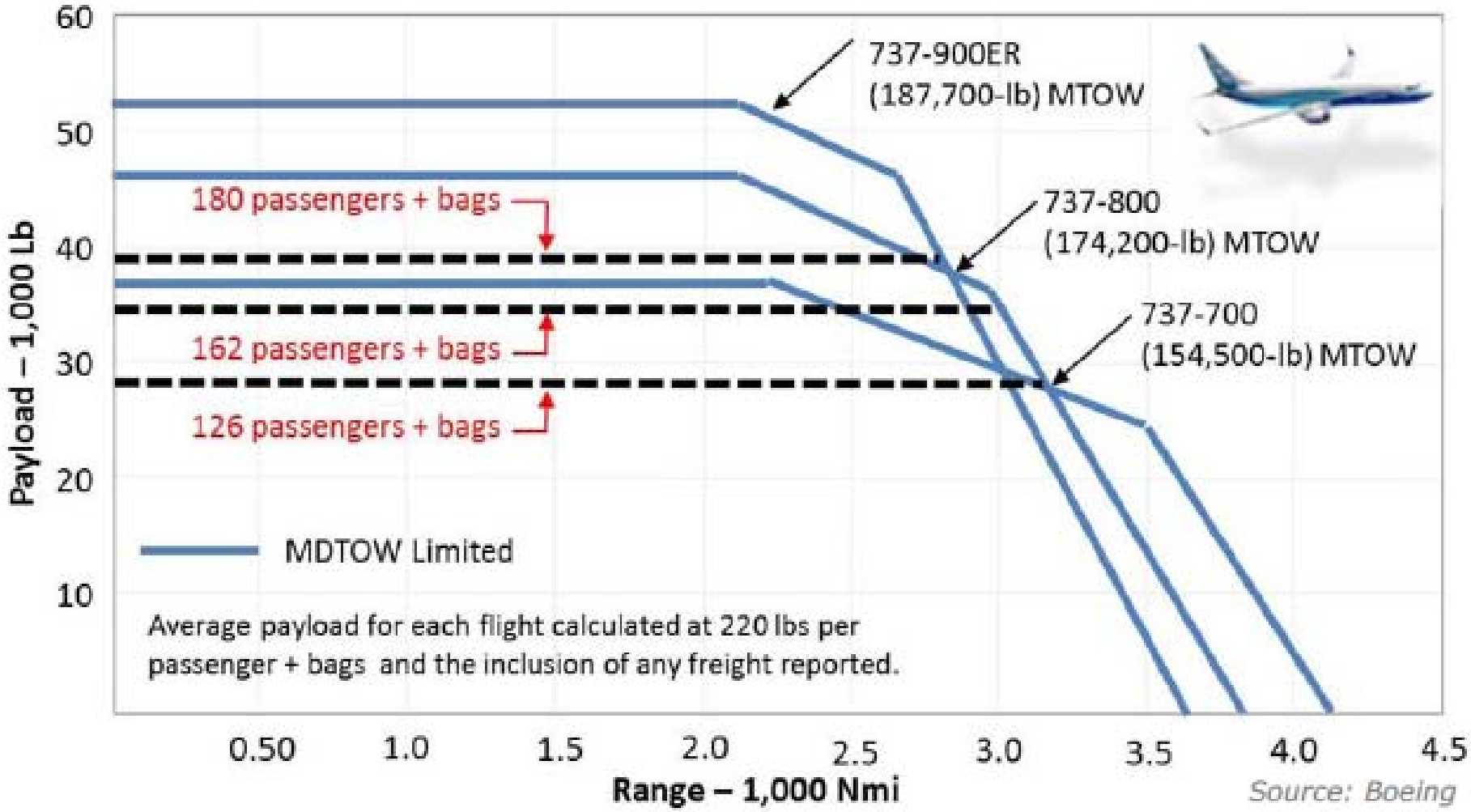
Quoted v/s Estimated RPD for Avro-RJ-100



Factors affecting RPD

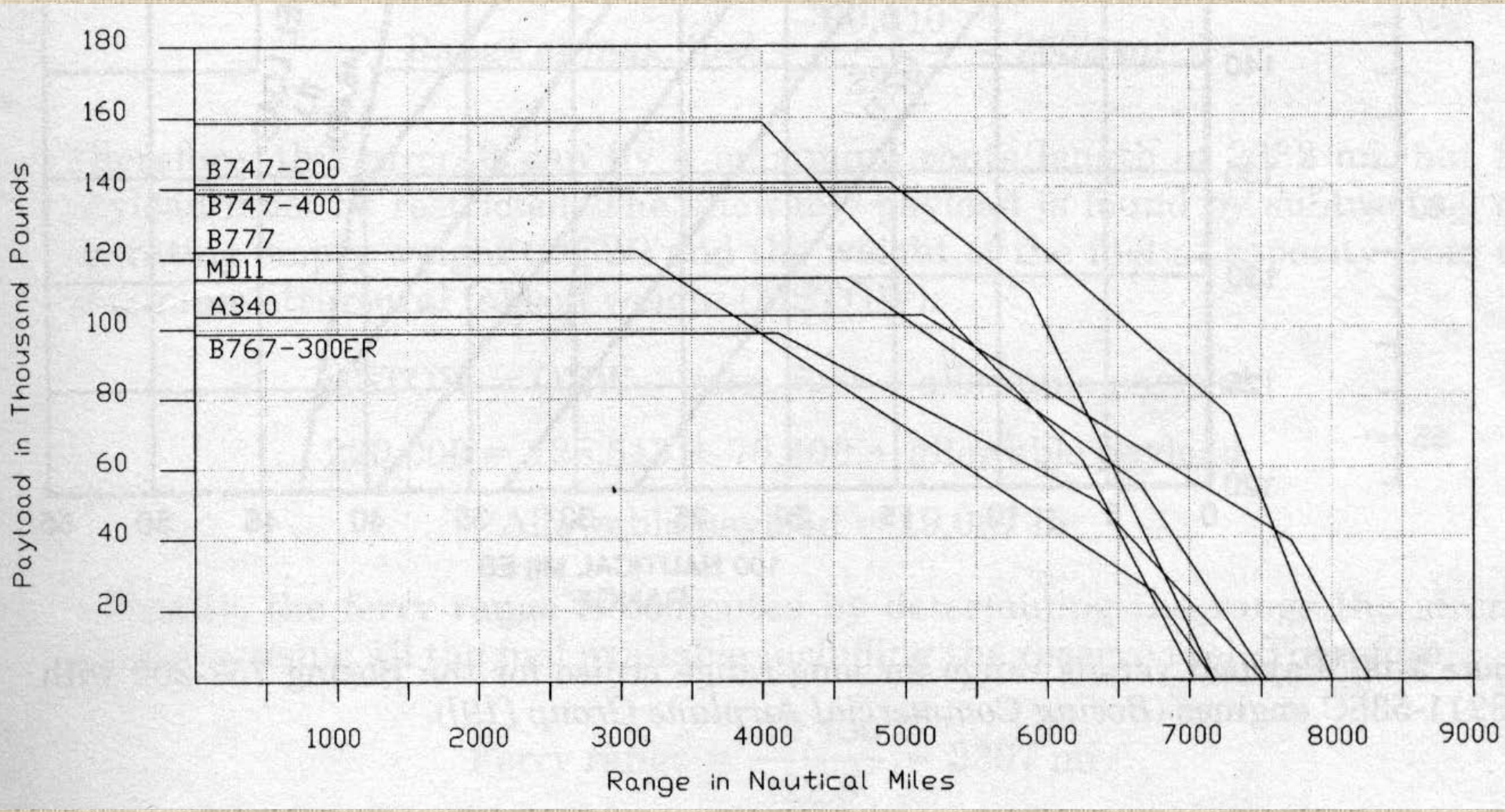
- Flight altitude
- Speed
- Powerplant
- Fuel
- Amount of reserve fuel to be carried
- En-route Meteorological conditions
  - For comparison of different aircraft, Payload range curves are usually shown for a standard day, no wind and long range cruise conditions

RPD for B-737 NG Family



Source: Ackert, S., Aircraft Payload-Range Analysis for Financiers, *Aircraft Monitor*, 2013

RPD for some Long-Range Transport a/c



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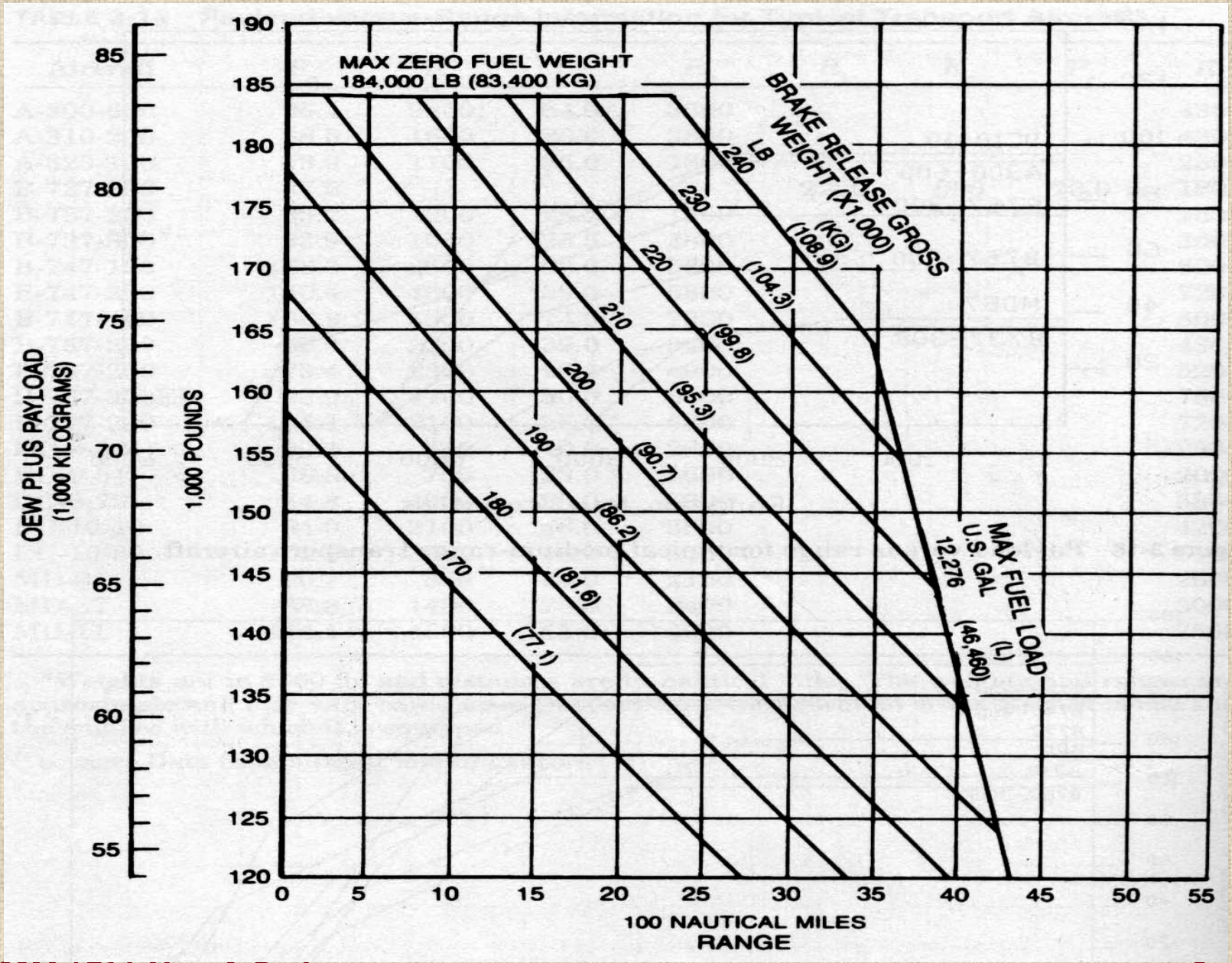
RPD for B-757-200 with RB-211-535C



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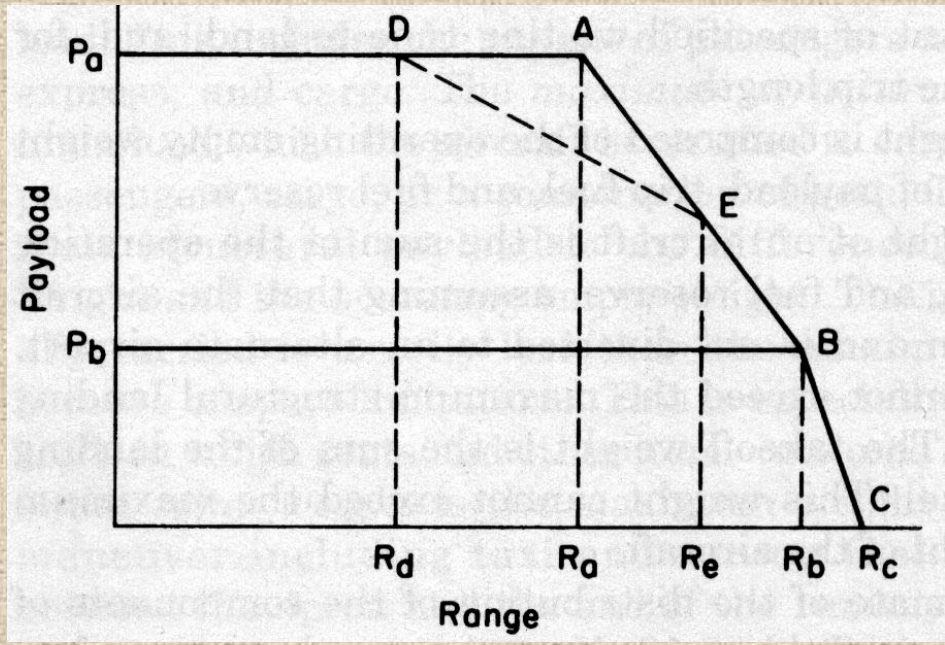
Effect of Winglets on RPD of B737-800

Source: Ackert, S., Aircraft Payload-Range Analysis for Financiers, *Aircraft Monitor*, 2013

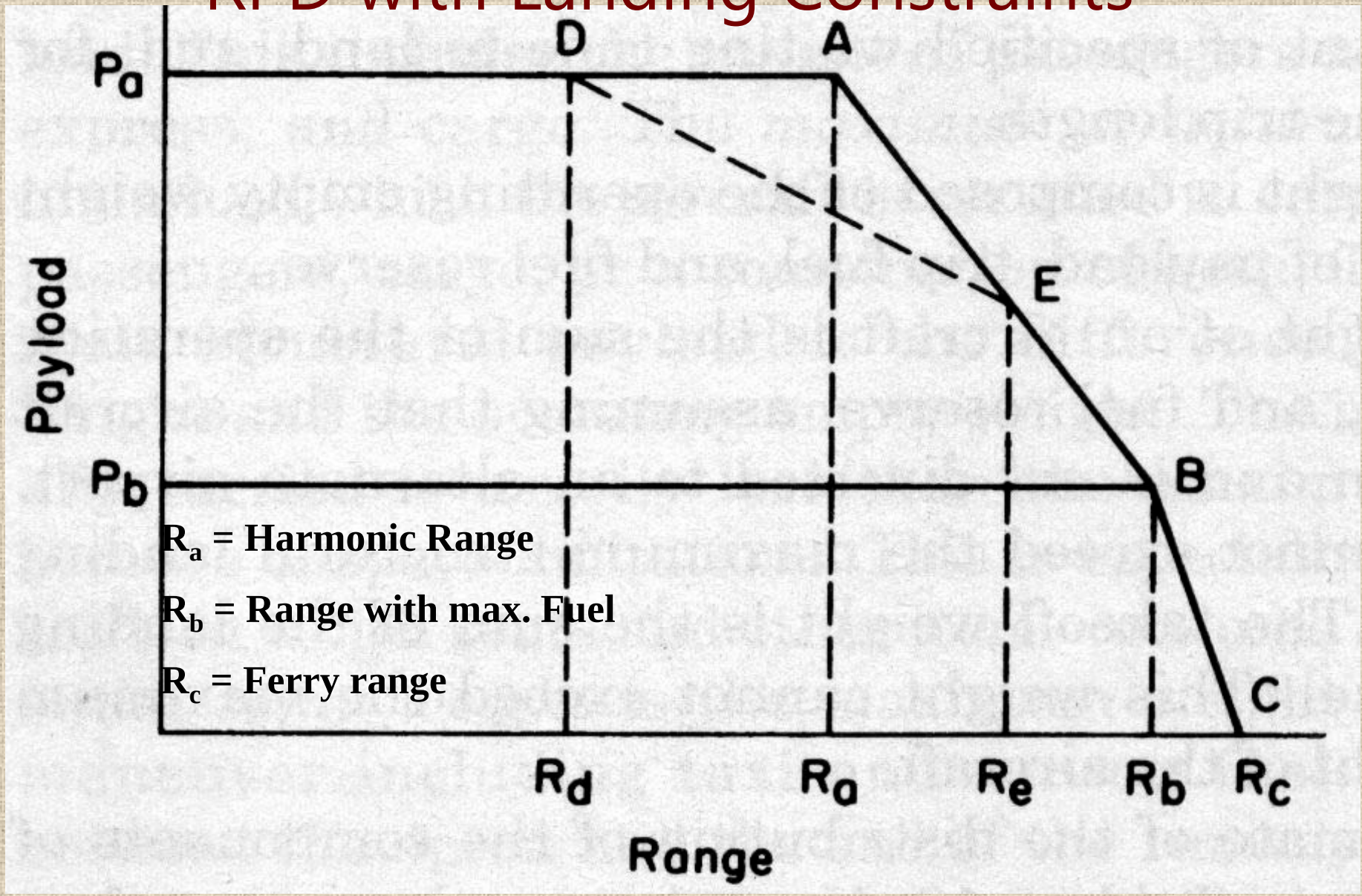
Effect of MLW on RPD

- MLW dictates Range
- At D, W_{Land} = permitted W_{TO}
- Range = R_d
- Line DE for payload tradeoff
- Curve DEBC is the RPD

  Rather than AEBC



RPD with Landing Constraints



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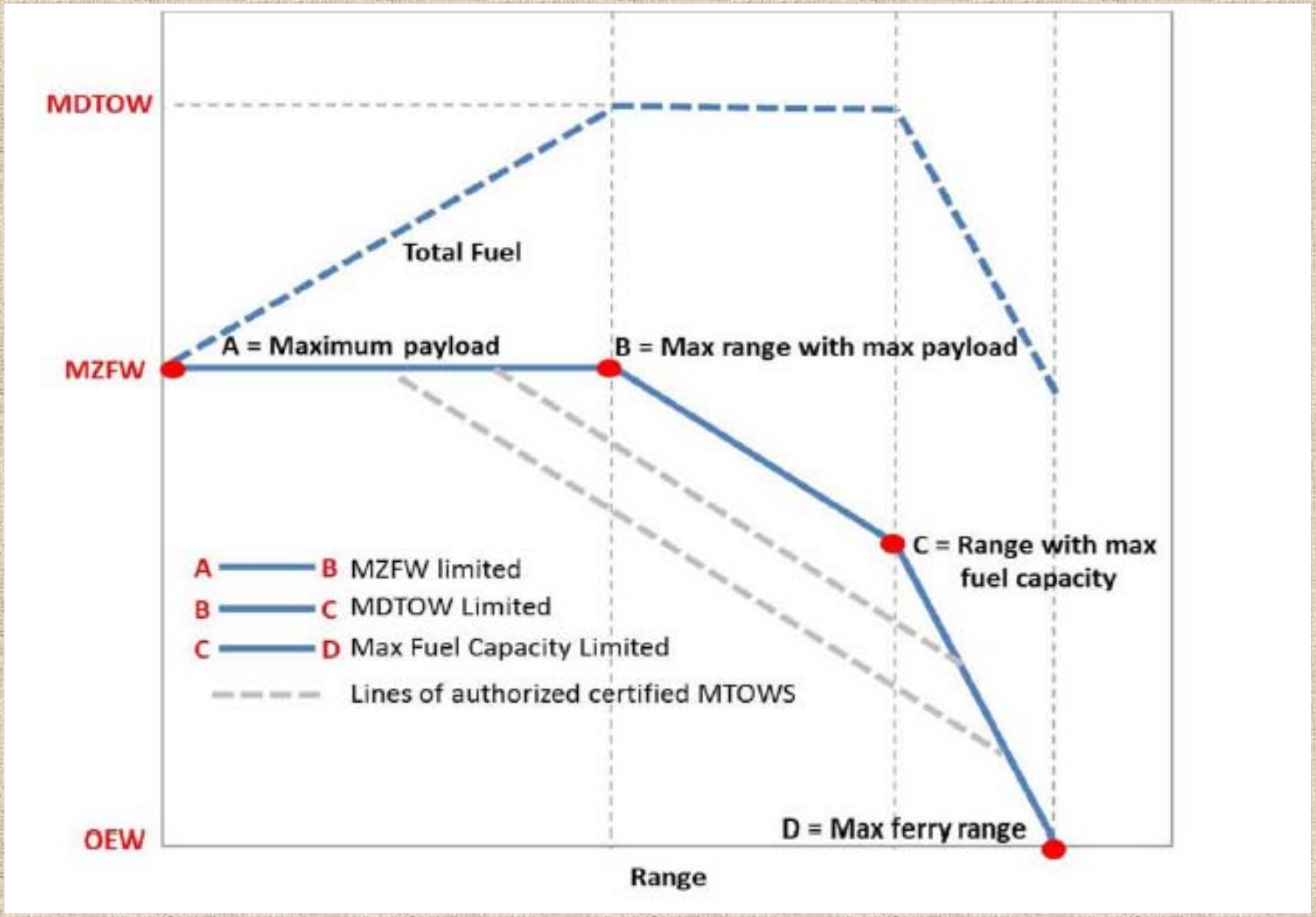
Alternate view of RPD



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1. Fielding, J. P., *Introduction to Aircraft Design*, Cambridge Aerospace Series 11, 1999.
2. Horonjeff, R., McKelvey, F., Sproule, W., Young, S., *Planning and Design of Airports*, 5th edition, McGraw Hill Professional, 2010
3. Ackert, S., Aircraft Payload-Range Analysis for Financiers, *Aircraft Monitor*, April 2013

ACKNOWLEDGEMENTS

Self-Study Assignment

Range Payload Diagram